LIMNOLOGICAL AND FISHERIES INVESTIGATIONS AT

SALMON LAKE, KARTA RIVER SYSTEM,

SOUTHEAST ALASKA

1998

by
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and
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Regional Information Report[1] No. 1J00-04

A final project report to the
Southern Southeast Regional Aquaculture Association
to fulfill obligations in cooperative agreement 99-007

Alaska Department of Fish and Game
Division of Commercial Fisheries
Juneau, Alaska

March 1999

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ACKNOWLEDGMENTS

The authors wish to thank Kim Vicchy, Andy Piston, Casey Stokes, Dan Patton, and all the other biologists, technicians, and volunteers who helped collect this data in mostly nasty weather conditions or at night. Thanks also to the dedicated biologists and technicians in the Limnology Lab in Soldotna who continue to analyze samples at the highest standards.

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ABSTRACT

The Salmon Lake sockeye salmon *Oncorhynchus nerka* fry stocking program was initiated in 1988 to help rehabilitate the depressed sockeye salmon population. Fry stocking occurred every year through 1997 at Salmon Lake. Zooplankton standing crop has remained stable for the past few years regardless of the level of lake stocking sockeye salmon fry. Zooplankton production and euphotic volume in 1998 was capable of sustaining sockeye densities far above the population observed in 1998. The fall rearing sockeye salmon fry population was estimated to be 72,817 fish on 2 November 1998. Based on standard survival assumptions this fry population should produce approximately 6,000 adult sockeye. Based on the ZB-EZD model, the optimum adult production capability of Salmon Lake was currently estimated at 84,000 adult sockeye. The stocking level of sockeye salmon fry could be increased from past levels without any negative impacts to the secondary production of Salmon Lake. The total harvest of Salmon Lake sockeye salmon in 1998 was estimated to be 10,583 fish, (9,128 commercial, 900 subsistence, and 555 sport). The escapement was estimated at 4,528 sockeye salmon in 1998, and the total adult return was estimated at 15,111 adults. The exvessel commercial value was estimated at $84,686. Based on 12% marine survival, the total adult return in 1999 is projected to be 32,978 sockeye salmon.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Salmon Lake, Karta River, Prince of Wales Island, Southeast Alaska, limnology, zooplankton, escapement, survival, rearing, hydroacoustics, mid-water trawl, commercial harvest, escapement, brood stock, mark-recapture population estimates, Darroch estimates, Petersen estimates, thermal marked otoliths, coded wire tags

INTRODUCTION

Most of the sockeye salmon populations in Southeast Alaska have been harvested intensely since the late 1800s. With this intensive harvest, runs became depressed and most have remained that way since. A plan to boost production by back planting fry was initiated at Salmon Lake in the early 1980s (Zadina 1998).

This report incorporates the results of continued studies from this rehabilitation program undertaken at Salmon Lake during the 1998 field season. These studies included: (1) recovery and analysis of coded-wire-tag data to determine the commercial harvest contribution, exploitation rate, and total adult return of Salmon Lake sockeye salmon; (2) recovery of thermal marked otoliths from the adult sockeye salmon return to determine the proportion of hatchery-reared fish; (3) assessment of the secondary production in the lake through limnological sampling; (4) estimation of the rearing sockeye salmon fry population through hydroacoustic sampling; (5) estimation of the adult spawning escapement through mark-recapture sampling; (6) determination of the individual brood year components of the total adult return through scale aging studies; and (6) estimate the total adult returns for 1999 and 2000.

STUDY SITE

Salmon Lake (55°34’29” N, 132°38’26” W) is located on Prince of Wales Island, 110 km northwest of Ketchikan in Southeast Alaska (Figure 1). The lake is organically stained with a surface area of 583 ha, mean depth of 27.6 m, maximum depth of 60 m, and volume of $140.0 \cdot 10^6$ m^3 (Figure 2). The lake empties into the Karta River, 4.6 km above Karta Bay in Kasaan Bay on the east side of Prince of Wales Island.

PROJECT SPONSORSHIP

The Southern Southeast Regional Aquaculture Association through the Alaska Department of Fish and Game provided funding to evaluate the limnological and lake stocking assessment program. This is the final report fulfilling contract obligations for Cooperative Agreement 99-007.

METHODS

Limnological Assessment

Limnological sampling was conducted at two stations on Salmon Lake, on 25 May, 27 June, 20 August, and 18 September, in order to evaluate lake productivity for rearing sockeye salmon fry.

Light Regime

Measurements of underwater light penetration (footcandles) were recorded at 0.5 m intervals, from the surface to a depth equivalent to one percent of the subsurface light reading, using a Protomatic[1] submarine photometer. Vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (ln of percent subsurface light) versus depth. The euphotic zone depth (EZD), the depth to which 1% of the subsurface light [photosynthetically available radiation (400-700nm)] penetrates the lake surface (Schindler 1971), was calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994). Euphotic volume (EV) is the product of the EZD and lake surface area and represents the volume of water capable of photosynthesis.

Secondary Production

Zooplankton samples were collected using a 0.5 m diameter, 153 μm mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a depth of 50 m to the surface at a constant speed of 0.5 m $\cdot$ sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed by the ADF&G, Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Cladocerans and copepods were identified using the taxonomic keys of Brooks (1957), Pennak (1978), Wilson (1959), and Yeatman (1959). Zooplankton were enumerated from three separate 1 ml subsamples taken with a Hensen-Stemple pipet and placed in a 1 ml Sedgewick-Rafter counting chamber. Zooplankton body length was measured to the nearest 0.01 mm from at least 10 organisms of each species along a transect in each of the 1 ml subsamples using a calibrated ocular micrometer (Koenings et al. 1987). Zooplankton biomass was estimated using species-specific dry weight vs. zooplankter length regression equations (Koenings et al. 1987). The seasonal mean density and body size was used to calculate the seasonal zooplankton biomass (ZB) for each species. Macro-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified.

Juvenile Sockeye Salmon Assessment

Rearing Fry Population

The distribution and abundance of rearing sockeye salmon fry was estimated by hydroacoustic and mid-water trawl sampling conducted in the fall. The lake was divided into eight sampling areas based on surface area. Sample design consisted of a series of eight stratified; randomly chosen orthogonal transects across the lake, one from each sampling area. Transect sampling was conducted during post-sunset darkness in one night. A constant boat speed of about 2.0 m $\cdot$ sec^{-1} was attempted for all transects. A Biosonics DT-4000 ™ scientific echosounder (420 kHz, 6° single beam transducer) with Biosonics Visual Acquisition © version 2.3.0 software was used to collect data. Ping rate was set at 5 pings $\cdot$ sec^{-1} and a 0.4 ms pulse width. Data was analyzed using Biosonics Visual Analyzer © version 2.1.1 software after returning to the office. Samples collected from mid-water trawls were used to estimate fish species and age composition. A 2 m × 2 m elongated trawl net was used for sampling. Trawl depths and durations were determined by fish densities and distributions throughout the lake based on observations during the hydroacoustic survey. Captured fish were euthanized in MS-222 prior to preservation in 70% ethanol. Samples were analyzed after a minimum of two weeks in preservative. Prior to measuring, the

[1] Mention of trade names does not constitute endorsement by Alaska Department of Fish and Game.

fish were soaked in freshwater for 30 minutes. The samples were blotted dry, measured to the nearest millimeter and weighed to the nearest 0.1 g. In addition, a preferred area scale smear (Clutter and Whitesel, 1956) was taken from each fish, affixed to a 2.5 cm × 7.5 cm glass slide, and aged using a television / video linked microscope.

Lake Rearing Model

This report uses a new model (ZB-EZD) that attempts to combine zooplankton biomass and euphotic zone depth. (Stan Carlson, ADF&G Commercial Fisheries, Soldotna, personal communication):

$$SB = 1.95(ZB) + 15.5(EZD) - 183.0,\ R^2 = 0.94$$

Where: SB = total smolt biomass ($kg \cdot km^{-2}$)
ZB = zooplankton biomass ($mg \cdot m^{-2}$)
EZD = euphotic zone depth (m)
Optimum smolt production individual fish weight is 4.0 g
Maximum smolt production individual fish weight is 2.4 g
Survival rate from spring fry to smolt is estimated at 20%
Survival rate from fall rearing fry to smolt is estimated at 70%

Adult Sockeye Salmon Assessment

Harvest Contribution

The commercial harvest contribution was estimated from coded-wire-tag returns. Hatchery reared Salmon Lake sockeye salmon fry and pre-smolts, tagged by SSRAA in 1994 and 1995, were expected to return in 1998 as ocean age-3, and age-2 adults, respectively. Coded-wire-tagged fish were recovered from the Alaska commercial salmon fisheries by the ADF&G Port Sampling Program as described by Oliver (1990). Tags were decoded at the ADF&G Coded Wire Tag and Otolith Processing Laboratory in Juneau. Equations for estimating the number of tags harvested by designated fishery strata are detailed in Clark and Bernard (1987). The calculations of fishery contribution and exploitation rate of Salmon Lake sockeye salmon follow Shaul (1994).

Salmon Lake sockeye salmon also contribute to the subsistence and sport fisheries. Subsistence harvest estimates were based on data from Alaska Department of Fish and Game, Subsistence Salmon and Personal Use Permits returned after the season. This permit is returned voluntarily. However, it is a mandatory return if the permit holder wants a new permit for the next year. An estimated sport fish harvest of 555 sockeye salmon was based on the mean 1986-1996 sport harvest of 555 sockeye (Mills, et al. 1986-1996). This harvest does not reflect the "sockeye released" in the annual statewide sport harvest studies. The actual 1998 sport harvest results for the Karta system will not be available until late-1999.

Escapement Estimate

A two-sample mark-recapture study was conducted at Salmon Lake in order to determine the size of the sockeye salmon spawning escapement. Marking was conducted on four two-day periods at 10-day intervals on 30 July, 11 August, 20 August, and 1 September. This sampling schedule was determined based on the timing of the sockeye salmon escapement from past surveys, and enabled marking to take place over the entire run. A large (37 m x 6 m) beach seine was used to capture sockeye salmon off the mouths of McGilvery and Andersen Creeks. Each fish was marked with a hole punch in the upper left operculum. Marking was stratified by time (a uniquely shaped hole punch was used for each marking period) and by location (fish captured off the mouth of McGilvery Creek were given a single punch, and fish captured off the mouth of Andersen Creek were given a double punch). Fish that were injured or otherwise appeared unhealthy were not marked. Stream surveys of McGilvery and Andersen Creeks were conducted approximately every 10 days from 30 July to 2 October to examine carcasses for marks. Carcasses were disfigured (when the heads were split open to remove otoliths) or were removed from the floodplain after examination for primary opercle punches to prevent duplicate sampling. In addition, spawning sockeye salmon were captured by dipnet, examined for marks, and given a secondary mark (another uniquely identifiable hole punch on the lower left operculum) to prevent duplicate sampling as carcasses at a later date.

Stratified Population Analysis System (SPAS) software (Arnason et al. 1996) was used to generate an estimate of the spawning population of sockeye salmon at McGilvery and Andersen Creeks. This program was used to analyze two-sample mark-recapture data in a stratified population, and computed, among other things, Darroch and pooled Petersen estimators, and tests for goodness-of-fit and the validity of pooling (as described by Seber 1982).

The estimated total adult return was the sum of the harvest contributions and the total escapement.

Escapement Sampling

The age composition of adult sockeye salmon was determined from a random set of scale samples collected at the mouth of McGilvery Creek over the course of the season, and expanded to the total adult return. Scale analysis was conducted at the ADF&G, Commercial Fisheries, Aging Lab in Douglas, Alaska. In 1995 SSRAA planted fry (373,204 in May) and pre-smolt (60,000 in October) from brood year 1994 back to Salmon Lake. Those releases were 100% thermal marked. The first returns of those releases were expected in 1998 as age 1.2 adults. Otolith samples were taken from all dead fish possible during escapement surveys in 1998, in order to determine the proportion of the age 1.2 escapement that was hatchery reared. Equations for estimating the number (and variance) of thermal marks in the population follow Clark and Bernard (1987), and Bernard and Clark (1996). Adult sockeye salmon were also sampled for missing adipose fins in order to determine the tagged to untagged ratio in the escapement. The otolith samples, and the heads of all adipose clipped fish, were sent to the ADF&G Coded Wire Tag and Otolith Processing Laboratory, Juneau, for analysis.

Projected Returns and Marine Survival

Projected adult returns at Salmon Lake were calculated from the hydroacoustic population estimate of rearing fall fry that produces an estimated smolt population. Standard survival and age at adult return assumptions derived from previous data at Hugh Smith and McDonald Lakes are presented in Table 1 (Zadina and Haddix, 1989). From these assumptions a matrix is produced which uses multiple brood years to produce estimated adult returns. When the actual adult population for each brood return and age composition are obtained they are entered into the matrix. The actual marine survival is calculated based on the corresponding juvenile estimate and adult return estimates.

RESULTS

Limnological Assessment

Light Regime

The euphotic zone depth (EZD) ranged from 4.86 m to 6.48 m, with an annual mean of 5.88 m. The mean EZD for 1992-1997 was 5.88 m. Euphotic volume (EV) in 1998 was estimated at $32.76 \cdot 10^6$ m^3 or 32.8 EV units. This volume capable of photosynthesis represents about 23% of the total lake volume.

Secondary Production

The seasonal mean total macrozooplankton population was 113,870 plankters $\cdot$ m^{-2} and the seasonal mean macrozooplankton biomass was 357 mg $\cdot$ m^{-2} in 1998 (Table 2). The macro-zooplankton community in Salmon Lake comprised three genera of copepods (*Cyclops*, *Diaptomus*, and *Epischura*) and four primary species of cladocerans (*Bosmina longirostris*, *Daphnia longiremus*, *Daphnia rosea*, and *Holopedium gibberum*). The dominant species by biomass was *Bosmina longirostris* (31.9%), followed by *Cyclops* spp. (12.9%), *Daphnia rosea* (14.4%), and *Holopedium gibberum* (14.2%). *Bosmina longirostris* was also the dominant species by density (53.2%), followed by *Cyclops* spp. (25.1%).

Juvenile Sockeye Salmon Assessment

The Salmon Lake hydroacoustic population estimate was conducted on 2 November 1998. Sockeye salmon fry constituted the entire fall rearing population estimate in 1998 with a total population of 72,817.

Adult Sockeye Salmon Assessment

Harvest Contribution

A total of 43 coded-wire-tagged Salmon Lake sockeye salmon were recovered from the Alaska commercial fisheries in 1998. Coded-wire tags were recovered from three ADF&G commercial fishing districts and from the Annette Island (MIC) harvest area (Table 3, Figure 3). The total estimated commercial harvest was 9,128 fish with an exvessel value estimated at $84,686.

Salmon Lake sockeye salmon were harvested from Statistical Weeks 26 to 31 and were harvested primarily in the District 106 drift gillnet fishery. This stock peaked early, with both total catch and catch-per-unit effort greatest in week 27, followed by a steady decline through week 31 (Figure 4 and 5).

The subsistence harvest was 459 sockeye from 27 returned permits as of 12 January 1999. That number is likely to increase through early 1999 as permits are turned in. The 1985-1997 mean subsistence harvest at Karta River was 1,386 sockeye salmon, from an average of 83 permits returned annually. Therefore, we are currently estimating a subsistence harvest of 900 sockeye salmon. The sportfish harvest is currently estimated at 555 sockeye salmon.

The total harvest of Salmon Lake sockeye salmon was estimated to be 10,583 fish (9,128 commercial, 900 subsistence, and 555 sport).

Escapement Estimate

A total of 1,489 sockeye salmon were marked with operculum punches at the mouths of McGilvery and Andersen Creeks. Few sockeye salmon were present at these two creek mouths on 30 July and 1 September. Beach seine catches were good on 11-12 August, and 20-21 August. There appeared to be free movement between the mouths of the two spawning creeks (less than 400 m), as fish marked at McGilvery Creek were caught at Andersen Creek within an hour of release, and vice versa. A small portion of the captured fish (15) died prior to marking. We assumed a low mortality rate on marked fish and reduced the total number of marks released by 1% to 1,474 in an effort to account for post-release mortality due to capture and handling (Appendix Table 1).

A total of 234 carcasses and live fish were examined for marks from the escapement of which 157 were marked fish. Not surprisingly, fish that were initially marked and released off the mouth of Andersen Creek were found spawning in McGilvery Creek and vice versa. Data collected from both streams were pooled into one data matrix for analysis in SPAS (Appendix Table 2). A pooled Petersen population estimate of 4,446 (s.e. = 398; 95 % normal C.I. 3,666 to 5,226) sockeye salmon was generated by the SPAS program. The Darroch estimate initially failed to converge, because triangle marked fish were not recovered, and no marked fish were recovered on the first recovery survey (see Appendix Table 2). Pooling all fish released with a star or triangle operculum punch, dropping the 1st recovery strata (no fish sampled) and pooling the 2nd and 3rd recovery strata, resulted in a Darroch population estimate of 4,022 (s.e. = 467; 95 % normal C.I. 3,107 to 4,938; Appendix Table 3). Chi-square test statistics gave a non-significant (p=0.47) result for the test of equal proportions of marks in the final strata, but gave a significant (p=0.03) result for the test of complete mixing of animals across the final strata independent of their initial stratum. Passing either of these tests (p>0.05) suggests that full pooling of the data is likely valid (Arnason et al. 1996). Therefore the pooled Petersen estimate was used as the final population estimate as it is more precise than the Darroch estimate.

Small numbers of sockeye salmon were also found spawning in the Karta River between Salmon and Karta Lakes. The peak survey there was 82 sockeye salmon on 16 September 1998. The total escapement to the Salmon Lake (Karta) system in 1998 was estimated at 4,528 (4,446 McGilvery and Anderson Creeks, and 82 Karta River).

Escapement Sampling

The age composition of the escapement was determined from 508 random scale sampled fish (Table 4). A total of 191 sockeye salmon carcasses were sampled for otoliths, of which 19 were brood year 1994 age 1.2 thermal marked fish. The total number of enhanced brood year 1994 age 1.2 fish in the escapement was estimated to be 442 (S.E.=94, CV=21.4%). That total represented 30.6% (S.E.=5.8%, CV=18.8%) of the total escapement of age 1.2 sockeye salmon at Salmon Lake in 1998.

Total Adult Return

Total adult return in 1998 was estimated at 15,111 sockeye salmon (4,528 escapement plus 10,583 harvest). The total exploitation rate on Salmon Lake sockeye salmon was estimated to be 70.0%, with 67.3% (95% C.I.=9.31%) harvested in the commercial fisheries.

Projected Adult Returns

The total adult return forecast for 1999 and current estimate for 2000 is 32,978 (38.3% enhanced) and 28,289 (39.5% enhanced) sockeye, respectively. This assumes a 12% marine survival and includes all age classes and combined enhanced and wild components (Table 5).

DISCUSSION

Zooplankton Abundance and Sockeye Fry Densities

Zooplankton productivity at Salmon Lake was above the 6 year mean (1992-1997), but has remained consistent on an annual basis (Figures 6 and 7). Macrozooplankton distribution by order also remained reasonably constant (Figures 8 and 9). The secondary production indicates an abundant food supply. The estimated pre-smolt sockeye salmon population of 58,254, based on fall hydroacoustics, was well below the optimum level of 700,000, 4.0 g smolt that the ZB-EZD model predicts.

Other models have been developed to estimate sockeye smolt production but are not used in this report. These models have limitations that are described in further detail. A euphotic volume (EV) model by Koenings and Burkett (1987) predicts the total smolt biomass (kg), based on the surface area and euphotic depth of a lake. This model only uses physical data derived from a particular lake and does not incorporate any biological information critical to a particular lake. For instance, a clear water system would appear to have higher productive capabilities over an organically stained system because of deeper light penetration. Another model was based on zooplankton biomass (ZB) and relates zooplankton standing crop to biomass ($kg \cdot km^2$) of sockeye salmon smolt (SB) produced annually in a non-fertilized, natural system (Koenings and Kyle 1997). The measurable standing crop of zooplankton represents the zooplankton biomass remaining after consumption by rearing sockeye juveniles. The unknown portion of the zooplankton production that was consumed was assumed to be proportional to the standing crop. Application of this model usually assumed the nursery lake would produce a maximum number of threshold size (about 63 mm and 2.0g) smolt at approximately twice the zooplankton standing crop (unless some information about smolt size is known). The ZB model was based on lakes considered to be at or near carrying capacity, thus it would be hard to predict how the model would perform for lakes under or over carrying capacity, (Stan Carlson, ADF&G Commercial Fisheries, Soldotna, personal communication).

Sockeye salmon fry survival for brood year 1997 was estimated at 17% of the predicted survival of green egg to spring fry, based on standard survival assumptions (Zadina and Haddix, 1989). An estimated 410,000 fall fry was predicted from an estimated escapement of 17,000 adults in 1997. This poor survival may be partly attributable to spawning habitat changes due to the very high rainfall recorded in the late fall of 1997. During the 1998 escapement surveys of McGilvery Creek we observed that some extreme bedload movements had occurred since our 1997 escapement surveys. Several large pools, which had been observed for years, were filled with gravel in 1998. Also several large logs, which had remained in place for many years, had moved a considerable distance downstream from their original location.

Adult Production

Normally the age 2-ocean fish comprised about 18% of the brood-year return based on standard survival assumptions. This component also provides an insight into the 3-ocean expectations for the next year. In 1997 the 2-ocean component (smolt year 1995) only comprised 4% of the total return. This represented only 35% of the forecasted 2-ocean group by brood year. The 3-ocean component of this smolt year returned at only 53% of the forecasted population in 1998. This represented a marine survival of approximately six percent. The low survival rate of smolt year 1995 was also found in other systems in southern Southeast Alaska in 1998, including McDonald and Hugh Smith Lakes, which indicated the problem probably was not associated with the freshwater environment. In 1998 the 2-ocean component returned at predicted levels indicating that the marine survival problem associated with smolt year 1995 may only have been temporary and may not affect smolt year 1996.

Good coded-wire-tag recoveries occurred in the first six weeks of the commercial fisheries in 1998. Recoveries indicated that catch per unit effort of Salmon Lake sockeye salmon in the District 106 drift gillnet fishery was highest in the opening weeks of the fishery and declined steadily after week 27. Because of the early migration timing, this stock has not been heavily exploited in the traditional seine fisheries which do not start until early July. If adult production can be increased it appears that the primary commercial harvest beneficiary will be the District 106 drift gillnet fishery unless a late June District 102 seine fishery can be incorporated which is directed at this stock.

RECOMMENDATIONS

At this time adult return evaluation should be focused primarily on escapement sampling for a population estimate and recoveries of coded wire tags and thermal marked otoliths. This can be accomplished with a mark-recapture estimate (Arnason et al. 1996) incorporated into systematic escapement surveys, similar to the program at McDonald Lake, to estimate total escapement. In 1999 the adults returning to Salmon Lake will have both coded wire tags and thermal marked otoliths. To fully evaluate both of these marking programs in 1999, it is imperative to sample for both marking types in the escapement. This recovery effort would produce an expansion of commercial harvest contributions for the total population rather than the current release marking fractions would for enhanced fish only.

Salmon Lake has never reached its optimum production potential of fall fry regardless of fry stocking or wild escapement levels. If the changing egg incubation environment at McGilvery Creek was the primary reason for decline in this stock then fry stocking should continue at Salmon Lake indefinitely. This hatchery effort could help increase fry production to approach optimization of the rearing environment.

The thermal marked otolith program should continue on any enhanced sockeye salmon program even though the otolith program was originally intended for evaluation of the rearing component only. Currently there is no area wide recovery program for adult otoliths in Southeast Alaska, but future applications for mass marking sockeye and chum salmon appear to be heading this direction versus the CWT program. Otolith marking is very cost effective and not labor intensive compared to CWT programs. This will continue to allow the ability to differentiate the survival rates of hatchery and wild fry, and to further utilize hatcheries at the most efficient means possible. Thermal marked otoliths will be a very important tool in the future for both management and hatchery program evaluation.

Evaluation of both the limnological and fisheries programs at Salmon Lake should continue until all hatchery incubated returns cease to exist.

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Table 1. Age distribution assumptions of adult sockeye salmon returning to Salmon Lake by brood year and return year.

Brood Year	Smolt Years	Projected Adult Age Distribution of Unknown Age Smolt	Adult Age Class	Return Year
1992	1994 or 1995	10.5%	1.2	1996
		65.1%	1.3	1997
		5.5%	2.2	1997
		18.0%	2.3	1998
1993	1995 or 1996	10.5%	1.2	1997
		65.1%	1.3	1998
		5.5%	2.2	1998
		18.0%	2.3	1999

Table 2. Seasonal mean macrozooplankton density and biomass distribution in Salmon Lake, 1998.

	Density		Biomass	
Species	No./m2	Percent	mg/ m2	Percent
Epischura	8,108	7.1%	79	22.2%
Diaptomus	314	0.3%	8	2.1%
Diaptomus - ovig.	21	0.0%	1	0.2%
Cyclops	27,910	24.5%	44	12.3%
Cyclops – ovig.	696	0.6%	2	0.6%
Bosmina	60,337	53.0%	114	31.8%
Bosmina – ovig.	185	0.2%	0	0.1%
Daphnia l.	1,055	0.9%	5	1.5%
Daphnia l. – ovig.	263	0.2%	2	0.5%
Daphnia r.	9,378	8.2%	44	12.2%
Daphnia r. – ovig	993	0.9%	8	2.2%
Holopedium	4,016	3.5%	39	11.0%
Holopedium – ovig.	592	0.5%	12	3.2%
Total	113,870		357	

Table 3. Distribution and value of the commercial harvest of Salmon Lake sockeye salmon, 1998.

District and Gear	Tags[a]	Sockeye	%	Exvessel Value
106 Gillnet	38	7,216	79.1%	$ 68,841
MIC Gillnet	1	173	1.9%	$ 1,566
Total Gillnet	39	7,389	80.9%	$ 70,407
102 Seine	3	1,573	17.2%	$ 12,916
104 Seine	1	166	1.8%	$ 1,363
Total Seine	4	1,739	19.1%	$ 14,279
Total Harvest	43	9,128	100.0%	$ 84,686

[a] Includes only randomly recovered tags.

Table 4. Age composition of the sockeye salmon escapement at McGilvery and Andersen Creeks, Salmon Lake, expanded to the total adult return, 1998.

Brood Year	Age	Sample Size	Percent	S. E.	Expanded Escapement	Expanded Adult Return
1995	1.1	12	2.4	0.7	107	363
1994	1.2	165	32.5	2.1	1,445	4,911
1994	2.1	3	0.6	0.3	22	76
1993	1.3	236	46.5	2.2	2,067	7,026
1993	2.2	14	2.8	0.7	124	423
1992	1.4	3	0.6	0.3	22	76
1992	2.3	75	14.8	1.6	658	2,236
	Total	508			4,446	15,111

Table 5. The projected total adult return of Salmon Lake sockeye salmon by age class and hatchery reared and wild components, 1999 and 2000.

Return Year	Brood Year	Age Class	Hatchery Reared	%	Wild	%	Total Adult Return
1999	1994	2.3	1,580	5%	1,282	4%	2,862
1999	1995	1.3	9,142	28%	15,752	48%	24,894
1999	1995	2.2	365	1%	1,480	4%	1,845
1999	1996	1.2	1,541	5%	1,836	6%	3,377
Total			12,628	38%	20,350	62%	32,978
2000	1995	2.3	1,097	4%	4,441	16%	5,538
2000	1996	1.3	8,092	29%	9,637	34%	17,729
2000	1996	2.2	761	3%	906	3%	1,667
2000	1997	1.2	1,215	4%	2,143	8%	3,358
Total			11,165	39%	17,127	61%	28,292

Table 6. Salmon Lake sockeye salmon coded-wire-tag release information for adults returning in 1998, from release years 1993 to 1996.

Tag Code	Returning Age Classes[a]	Release Date	Number Tagged	Number Released	Tag Value	Tags Recovered Escapement	Tags Recovered Fishery
401021201	2.3	19-May-93	11,791	173,144	14.68		
401021202	2.3	19-May-93	11,939	175,382	14.69		
401021203	2.3	19-May-93	11,965	175,688	14.68		
401021204	2.3	19-May-93	11,586	170,194	14.69		
401021205	2.3	19-May-93	10,353	152,086	14.69		
401021206	2.3	19-May-93	11,633	170,806	14.68		
401021501	1.3 or 2.2	05-May-94	10,964	89,733	8.18		1
401021502	1.3 or 2.2	05-May-94	11,407	89,530	7.85	1	1
401021503	1.3 or 2.2	12-May-94	11,679	87,091	7.46		
401021504	1.3 or 2.2	12-May-94	10,766	80,392	7.47		2
401021505	1.3 or 2.2	17-May-94	10,655	211,735	19.87		
401021506	1.3 or 2.2	17-May-94	10,976	217,747	19.84		
401021508	1.3 or 2.2	27-Oct-94	4,864	33,115	6.81	3	4
401030410	1.2 or 2.1	17-May-95	10,951	61,952	5.66		
401030411	1.2 or 2.1	17-May-95	10,630	59,746	5.62		1
401030412	1.2 or 2.1	17-May-95	10,868	63,606	5.85		1
401030413	1.2 or 2.1	17-May-95	10,823	63,606	5.88		
401030414	1.2 or 2.1	17-May-95	10,856	62,147	5.72	1	
401030415	1.2 or 2.1	17-May-95	10,820	62,147	5.74		
401030501	1.2 or 2.1	26-Oct-95	11,035	30,000	2.72	10	18
401030502	1.2 or 2.1	26-Oct-95	10,978	30,000	2.73	9	15
401030704	1.1	15-May-96	12,610	71,286	5.65		
401030705	1.1	15-May-96	11,701	65,803	5.62		
401030706	1.1	15-May-96	12,187	93,349	7.66		
401030707	1.1	15-May-96	12,425	94,855	7.63		
401030708	1.1	15-May-96	12,247	103,121	8.42		
401030709	1.1	15-May-96	12,009	101,079	8.42		

[a] First age class listed is the predominate age class.

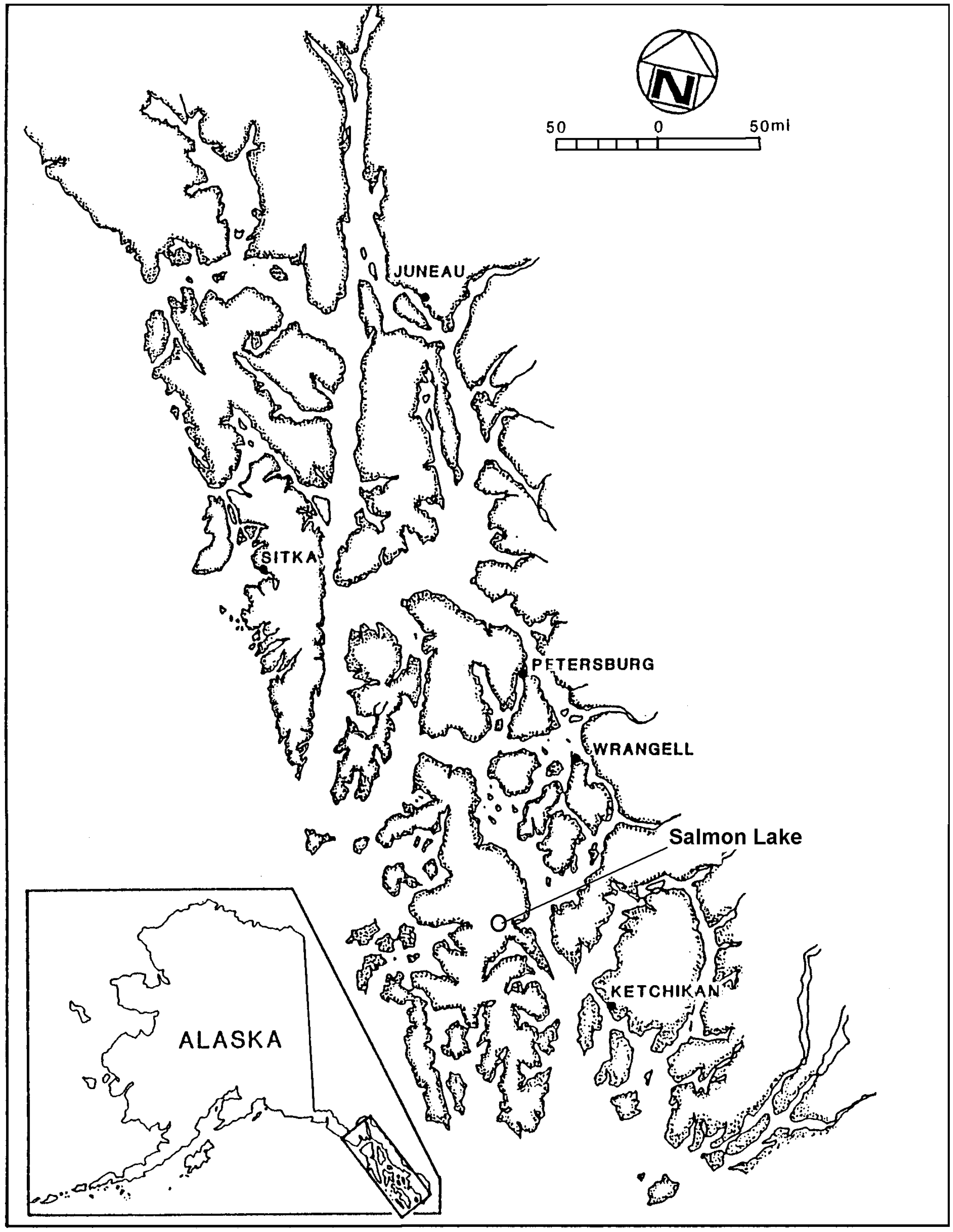

Figure 1. The geographic location of Salmon Lake, Prince of Wales Island, Southeast Alaska.

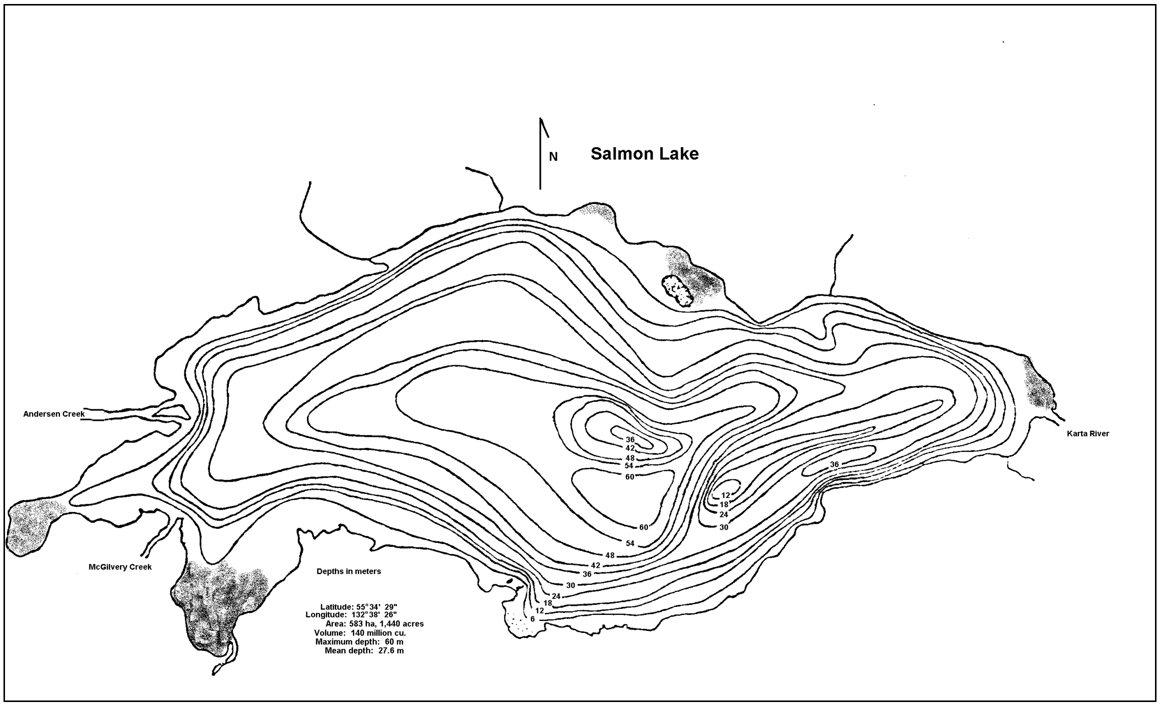

Figure 2. Bathymetric map of Salmon Lake, Prince of Wales Island, Southeast Alaska.

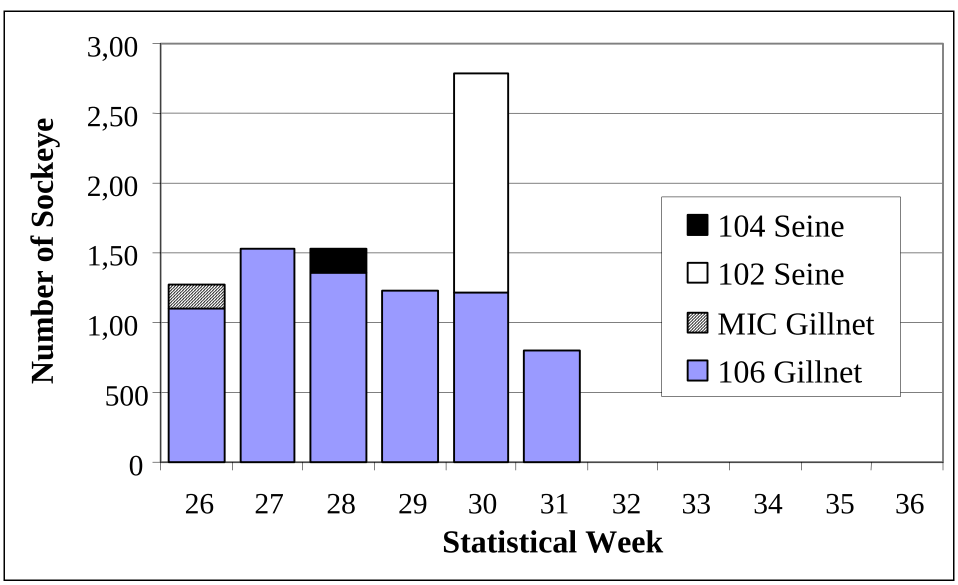

Figure 3. Estimated commercial harvest of Salmon Lake sockeye salmon by District and statistical week, 1998.

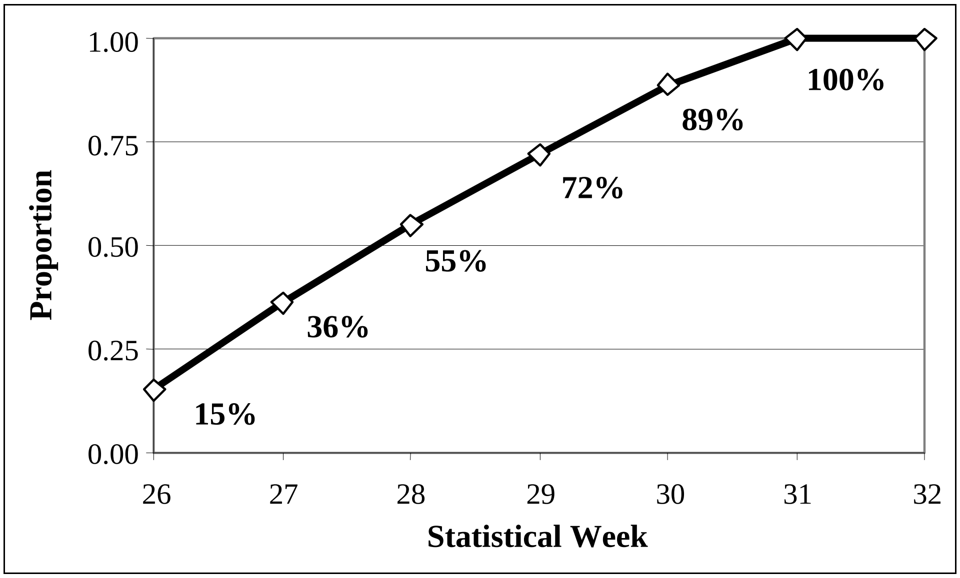

Figure 4. Run timing of Salmon Lake sockeye salmon through the District 106 drift gillnet fishery, illustrated by cumulative weekly harvest proportion, 1998.

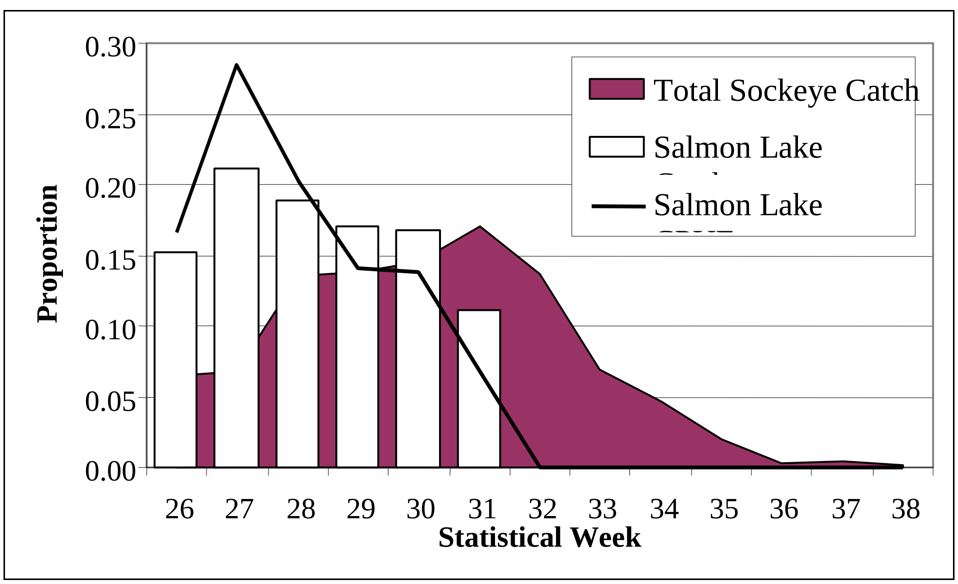

Figure 5. Weekly proportions of (1) the total sockeye salmon harvest, (2) the estimated catch of Salmon Lake sockeye salmon, and (3) the estimated CPUE of Salmon Lake sockeye salmon in the District 106 drift gillnet fishery, 1998.

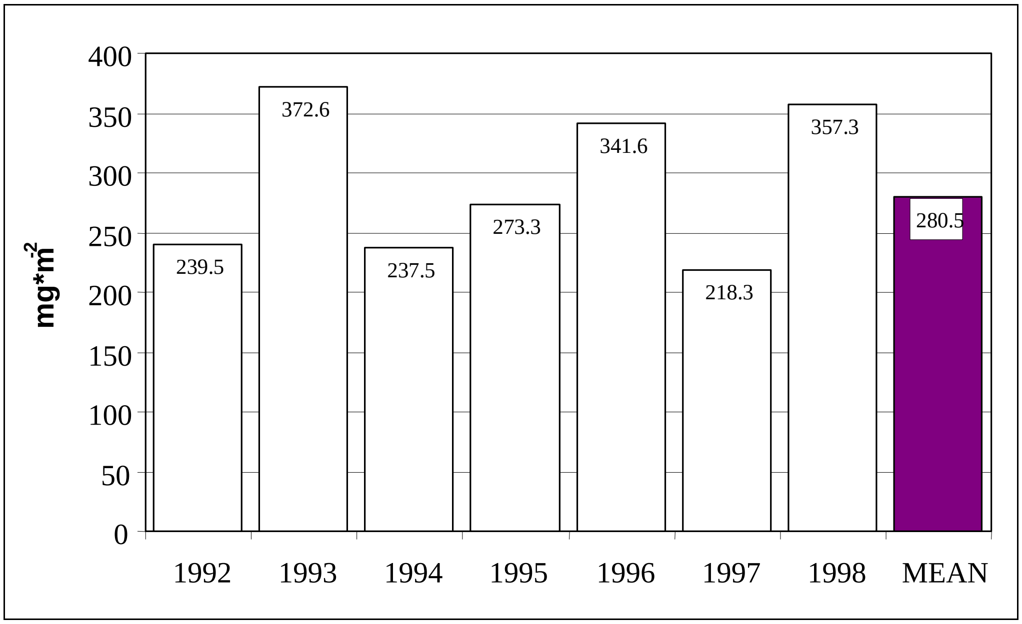

Figure 6. Mean Seasonal macrozooplankton biomass (mg * m^{-2}) at Salmon Lake from 1992 to 1998, and seven-year mean.

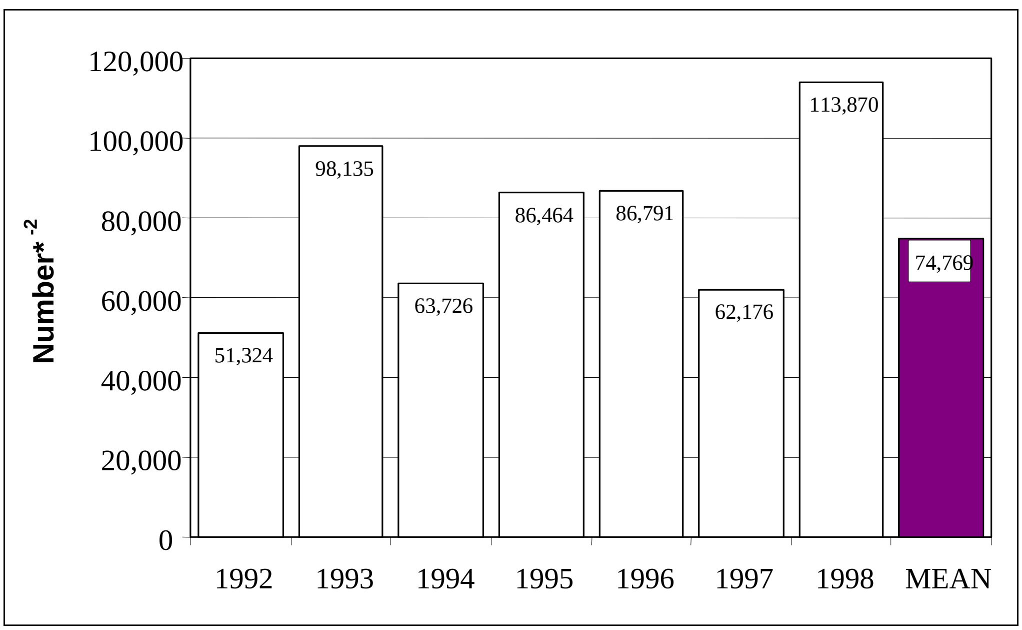

Figure 7. Mean seasonal macrozooplankton density (number * m^{-2}) at Salmon Lake from 1992 to 1998, and seven-year mean.

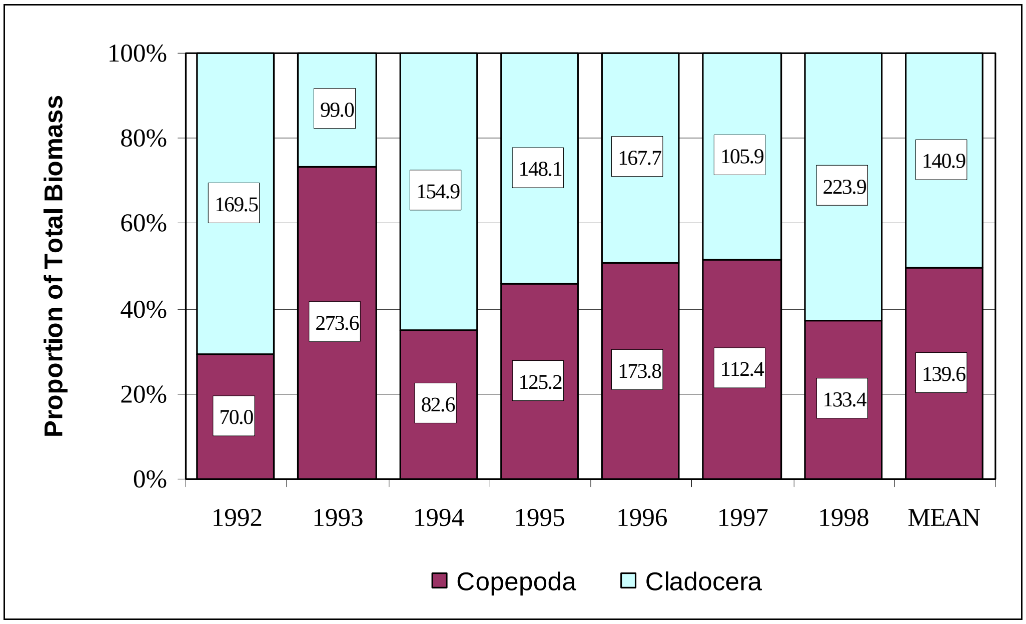

Figure 8. Mean seasonal distribution of macrozooplankton biomass (mg * m^{-2}) by plankter order at Salmon Lake from 1992 to 1998, and seven-year mean.

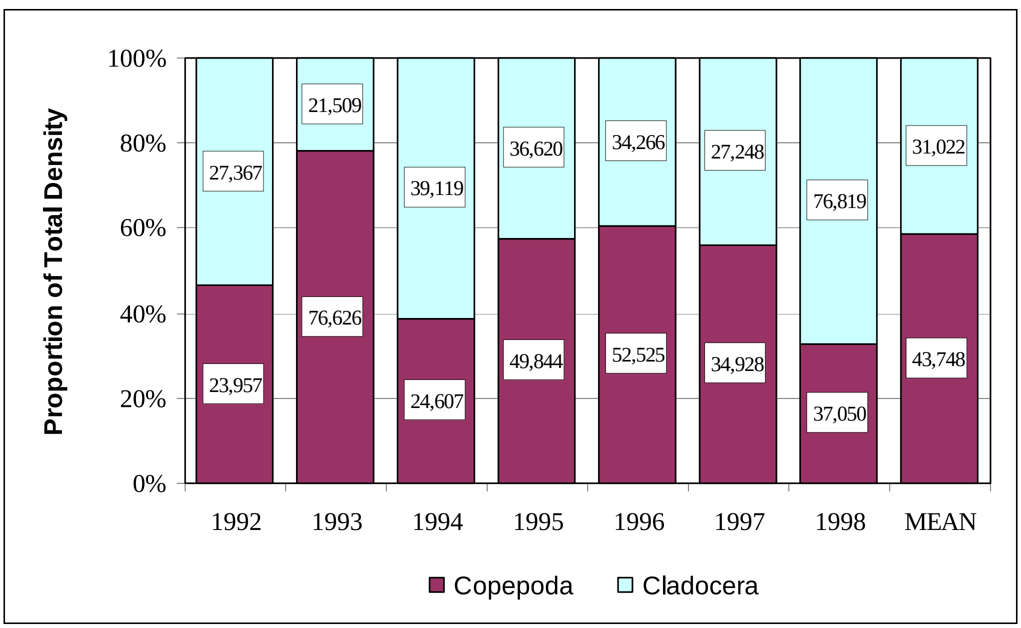

Figure 9. Mean seasonal distribution of macrozooplankton density (number * m^{-2}) by plankter order at Salmon Lake from 1992 to 1998, and seven-year mean.

APPENDIX

Appendix A.1. Total number of marked adult sockeye salmon released at the mouths of McGilvery and Andersen Creeks, Salmon Lake, 1998.

Date	Operculum Punch	Creek	Total Marked
30 Jul	Square	McGilvery	3
11-12 Aug	Square	McGilvery	816
11-12 Aug	double square	Andersen	121
20-21 Aug	Star	McGilvery	480
20-21 Aug	double star	Andersen	49
1 Sep	Triangle	McGilvery	4
1 Sep	double triangle	Andersen	1
Total			1,474

Appendix A.2. Total number of marked and unmarked adult sockeye salmon recovered at McGilvery and Andersen Creeks, Salmon Lake, 1998.

Operculum	Carcass Survey Date							
Punch	12-Aug	21-Aug	4-Sep	16-Sep	17-Sep	18-Sep	2-Oct	Total
Square	-	-	8	5	7	4	8	32
Double square	-	-	-	2	4	1	3	10
Star	-	-	1	2	13	11	4	31
Double star	-	-	-	-	1	2	1	4
Triangle	-	-	-	-	-	-	-	-
Double triangle	-	-	-	-	-	-	-	-
Total Unmarked	-	2	9	20	61	26	39	157
Total Sampled	-	2	18	29	86	44	55	234

Appendix A.3. Analysis of 1998 Salmon Lake adult sockeye salmon mark-recapture data (Appendix Table 2) by stratified population analysis system (SPAS) software (Arnason et al. 1996). All fish marked with a star or triangle operculum punch were pooled into one release stratum (“Star + Triangle”). Data collected on 21 August and 4 September were pooled into one recovery stratum (“1+2”).

Chi-square Test Statistics:
Complete Mixing: 6.96 (2 df) Significance... 0.03
Equal Proportions: 3.58 (4 df) Significance... 0.47

ML Darroch Estimate:
Total Number of iterations is 3 (Max iterations is 25)
Estimate (std. err): 4,022 (467)
Log likelihood: 480.97
95 % normal C I: (3,107, 4,938)
G-square: 0.22 (2 df), Significance… 0.90
Chi-square: 0.22 (2 df), Significance… 0.90

Table of Stratum Estimates & Predicted counts N(cap), m(cap, rec), u(rec)

	Stratum	S.E.		S.E.	Recovery Stratum				
Release Stratum	Size	(Size)	P(capture)	(P(Capture))	1+2	3	4	5	6
Square	1,799.42	509.75	0.4551	0.1289	8.13	4.81	7.12	3.94	8.00
2-Square	1,095.35	501.85	0.1114	0.0510	0.00	1.60	4.49	0.92	2.99
Star +Triangle	1,127.66	512.96	0.4735	0.2154	1.01	1.93	14.23	12.82	5.00
Unmarked					10.86	20.66	60.16	26.31	39.01

Least squares Estimate:
Estimate (std. err): 3,986 (-1.00)
G-square: -3.40 (2 df), Significance… 2.00
Chi-square: 1.61 (2 df), Significance… 0.45

Table of Stratum Estimates & Predicted counts N(cap), m(cap, rec), u(rec)

	Stratum		Recovery Stratum				
Release Stratum	Size	P(capture)	1+2	3	4	5	6
Square	1,647.21	0.4972	8.06	4.88	7.10	3.95	8.00
2-Square	1,140.18	0.1070	0.00	1.61	4.48	0.89	3.01
Star +Triangle	1,200.80	0.4447	1.01	1.94	14.25	12.79	5.00
Unmarked			9.34	24.25	57.94	28.62	39.37

Pooled Petersen Estimate:

Estimate (std. err): 4,446 (398)
95 % normal C I: (3,666, 5,226)
95 % transform C I: (3,749, 5,327)